# DESIGN AND MANUFACTURING OF PART TRANSFER MECHANISM ON ALFING MACHINE

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**Abstract -** *In ALFING machine part transfer mechanism is used to transfer crankshaft from the parking lot to the spindle of the machine. ALFING is an induction hardening machine used to harden crankshafts. The existing part transfer mechanism consists of a hydraulic cylinder mounted on a linear motion bearing. The coolant used for quenching operation is ethylene glycol which corrodes the linear motion bearing which leads to frequent breakdown of the machine. The project aim is to eliminate the existing linear motion bearing by a new simpler part transfer mechanism. The working principle of the new part transport mechanism is based on gravity principle. The new mechanism consists of two plates mounted on a hydraulic cylinder. The forward stroke of hydraulic cylinder provides the required inclination for the crankshaft to travel to gain linear motion along the surface of the plate. After reaching the required destination another actuator is used to lift the crankshaft to the machine spindle. Hardened crankshaft is unloaded with the help of actuator. The return stroke of the hydraulic cylinder provides negative inclination which forces the crankshaft to roll to the parking lot.*

***Key Words***: ALFING, mechanism, hydraulic, crankshaft, actuator, forces

## 1. INTRODUCTION

The main function of part transfer mechanism is to move parts from one station to the other in least possible time and maximum possible efficiency. There are linear part transfer mechanisms used to provide linear travel for in-line machines and rotary part transfer mechanism used to provide rotary motion for dial indexing machine. Failure of part transfer mechanism results in the failure of the whole line thus, adversely affecting the production of the plant. Therefore to increase the production of the plant it is important that the part transfer mechanism should work efficiently. For efficient working of the part transfer mechanism, the factors affecting the mechanism and the environment in which it is working should be considered while designing.

### 1.1 ALFING machine

"ALFING" is an induction hardening machine used to harden crankshafts.
"ALFING MACHINE" may only be used for inductive surface hardening of one crankshaft type with:-

- Work piece length: 600 to 1500 mm
- Maximum tool trace diameter: 330 mm
- Pin bearing diameter: 60 to 115 mm
- Pin bearing width: 30 to 76 mm
- Stroke: 40 to 100 mm
- Main bearing diameter: 70 to 140 mm
- Main bearing width: 35 to 76 mm
- Flange diameter: 100 to 180 mm
- Low end diameter: 40 to 150 mm
- Maximum weight: 250 kg

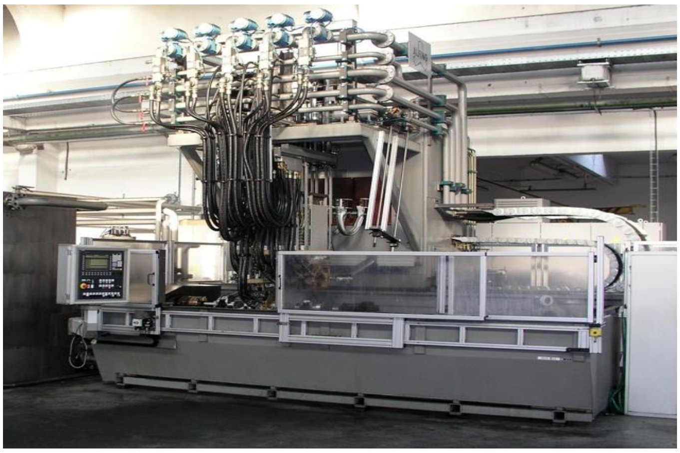

**Fig -1**: Alfing Machine.

### 1.2 Hardening

Induction hardening is a form of heat treatment in which a metal part is heated by induction heating and then quenched. The quenched metal undergoes a martensitic transformation, increasing the hardness and brittleness of the part. Induction hardening is used to selectively harden areas of a part or assembly without affecting the properties of the part as a whole. The generated electric current in varying magnetic fields known as "EDDY CURRENT". These eddy currents generated are responsible for the heating up of the work piece. Induction heating is a non-contact heating process which utilizes the principle of electromagnetic induction to produce heat inside the surface layer of a work-piece. By placing a conductive material into a strong alternating magnetic field, electrical current can be made to flow in the material thereby creating heat due to the $I^2R$ losses in the material. The current generated flows predominantly in the surface layer, the depth of this layer being dictated by the frequency of the alternating field, the surface power density, the permeability of the material, the heat time and the diameter of the bar or material thickness. By quenching this heated layer in water, oil or a polymer based quench the surface layer is altered to form a martensitic structure which is harder than the base metal it is a widely used process for the surface hardening of steel. The components are heated to a temperature within or above the transformation range followed by immediate quenching. The core of the component remains unaffected by the treatment and its physical properties are those of the bar from which it was machined, whilst the hardness of the case can be within the range 37/58 HRC. Carbon and alloy steels with an equivalent carbon content in the range 0.40/0.45% are most suitable for this process.

## 2. WORKING OF PART TRANSFER MECHANISM

The main principle of working of the part transfer mechanism is based on gravity. The change in the inclination of the plate leads to the transfer of crankshaft. Firstly, a vertical GUDEL (A vertical linear motion bearing) brings the crankshaft to the parking lot and unloads the crankshaft to the plate. The GUDEL is synchronized with the CNC line. After the part has been loaded to the plate a proximity sensor senses the crankshaft and sends a signal to the controller. The controller actuates the hydraulic pump which causes the forward stroke of the hydraulic cylinder. The forward stroke of the hydraulic cylinder provides a positive inclination to the plate and the crankshaft rolls on the plates and the rolling motion of the plate is obstructed by a groove provided on the plate just below the spindle of the machine. After the crankshaft has reached to this position another proximity sensor senses the crankshaft and actuates the forward stroke of the second cylinder. This hydraulic cylinder lifts the crankshaft to the spindle height and the main journal bearings of the crankshaft are clamped in the spindle. After clamping, the place where the big end of the connecting rod is to be attached i.e. the connecting rod journal is hardened with the help of induction hardening.

After the hardening process is complete, the hydraulic cylinder lowers the finished crankshaft and rests it on the plate. The position of the crankshaft is sensed by the proximity sensor and it actuates the main hydraulic cylinder. This actuation of sensor leads to the return stroke of the cylinder and a negative inclination is provided on the plate. This inclination imparts a forward motion to the crankshaft and the crankshaft is brought back to the original position. The proximity sensor senses the arrival of the part and sends a signal to the GUDEL. The GUDEL then grabs the hardened crankshaft with the help of an electrically operated rack and pinion arrangement. Another GUDEL rests the raw crankshaft on the plate and the cycle continues so on. To increase the probability of the crankshaft to exactly stop in the groove below the machine spindle an electrically operated stopper is placed just after the groove. This stopper allows the exact positioning of the crankshaft and thus increases the precision of the mechanism. The stopper may be electrically operated, pneumatically operated or hydraulically operated based on the place available. The stopper is actuated by a proximity sensor, which senses the arrival of the crankshaft in its vicinity. The distance of placing the proximity sensor should depend on the time taken by the stopper to fully operate. If the distance is less the stopper will not fully extend and there is a possibility of misalignment of the crankshaft with respect to the machine spindle. In order to avoid the misalignment of the crankshaft the response time of the stopper is a very important factor.

## 3. DESIGNING OF PART TRANSFER MECHANISM

### 3.1 Design of Plate

Material selected for plate is 22 Cr 13 S 28 (Alloy Steel) having yield strength of
500 $N/mm^2$ and mass density of 7800 $kg/m^3$.Volume of each plate is 0.018456 $m^3$.

Weight of each plate W= ρ×volume of plate
= 7800×0.018456
= 143.95 kg.

Force acting on each plate due to its own weight at C.G
= W×9.81
= 143.95×9.81
= 1412.2325 N.

Force acting on each plate due to weight of crankshafts
= 5311.134 N

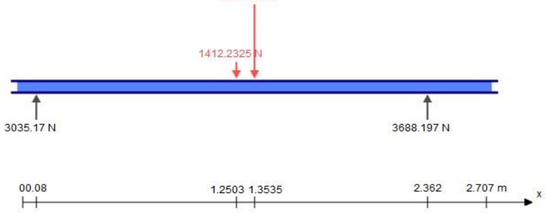


**Fig -2**: FBD of plate

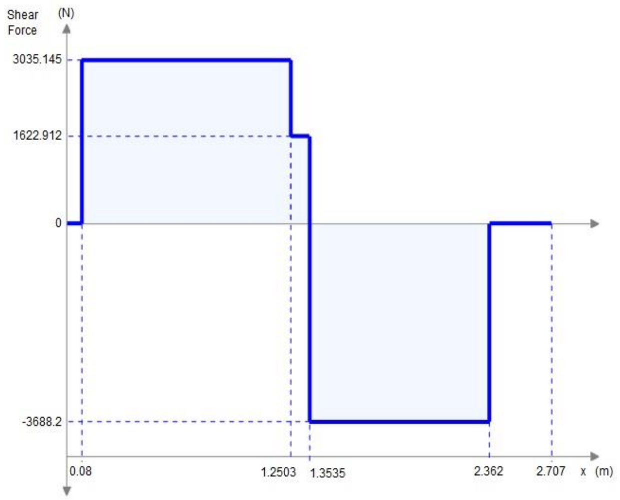


**Fig -3:** SFD of plate

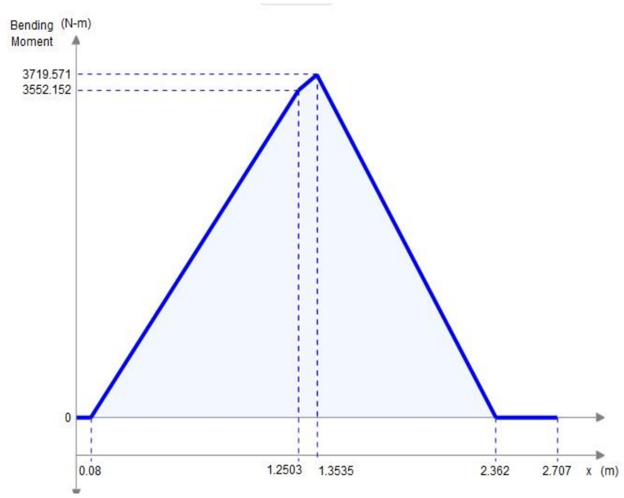


**Fig -4**: BMD of plate

For Thickness of plate

$$\sigma = \frac{M}{Z}$$

Bending stresses = $\frac{s_{yt}}{f}$

=500/15

=33.333 N/mm$^2$

M= Maximum bending moment

f=factor of safety=15

Sectional modulus= $\frac{bh^2}{6}$

b is Plate width and h is minimum distance from bottom of plate

Therefore,

b= $\frac{6M}{\sigma h^2}$

b= (6 × 3719.571 × 10$^3$ /33.333 × 158.629$^2$)

b=26.607 mm

b=30 mm.

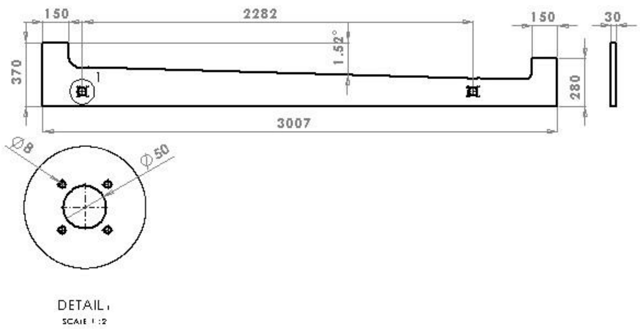


**Fig -5**: Drafting of plate

### 3.2 Design of Shaft 1

Material selected for shaft is 20 Cr 18 Ni 2 (Alloy Steel) having yield strength of 700 N/mm$^2$ and mass density of 7800 kg/m$^3$.

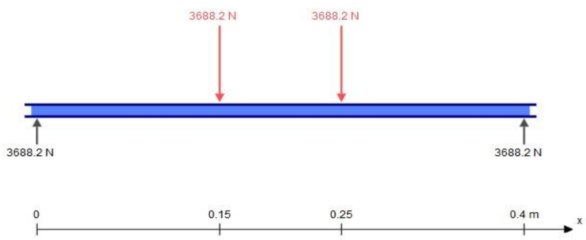


**Fig -6**: FBD of shaft 1

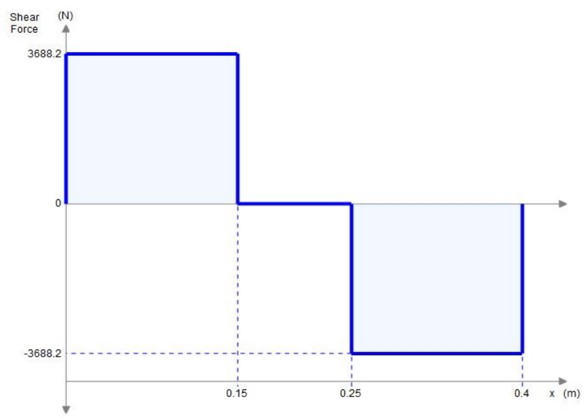


**Fig -7**: SFD of shaft 1

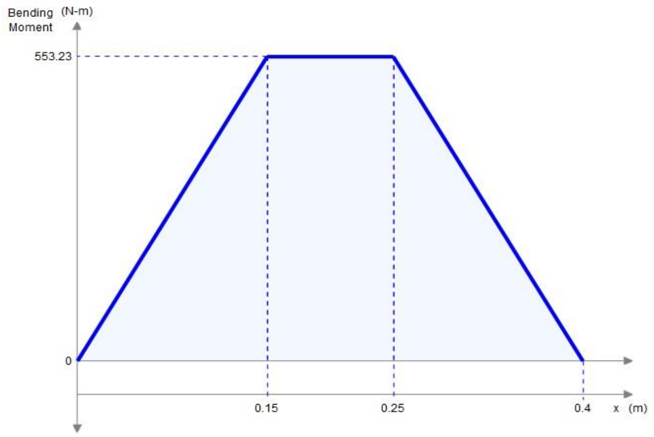


**Fig -8**: BMD of shaft 1

Maximum bending moment of shaft1=553.23×$10^3$ N-mm
According to bending equation,

$$\frac{\sigma}{y}=\frac{M}{I}$$

Where,
$\sigma$=Bending stress=$\frac{s_{yt}}{f}$ =700/15 =46.666 N/mm$^2$
M= Maximum bending moment
f=factor of safety=15
y=Distance from neutral axis=d/2
I=Moment of inertia=$\pi d^4/64$
Therefore,
$d^3=\frac{64\times M}{2\sigma\pi}$

d =49.427 mm
d =50 mm

### 3.3 Design of Shaft 2

Material for shaft2 is same as shaft1.Since shaft1 is subjected to less load as compared to shaft2,hence d=50 mm will be safe for shaft2.

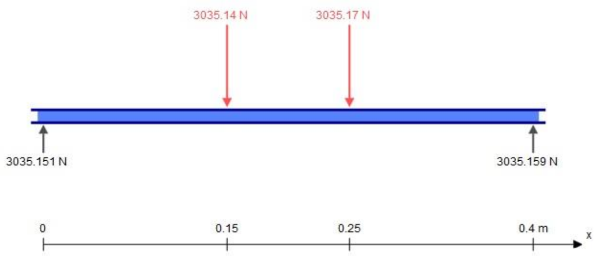


**Fig -1**: FBD of shaft 2

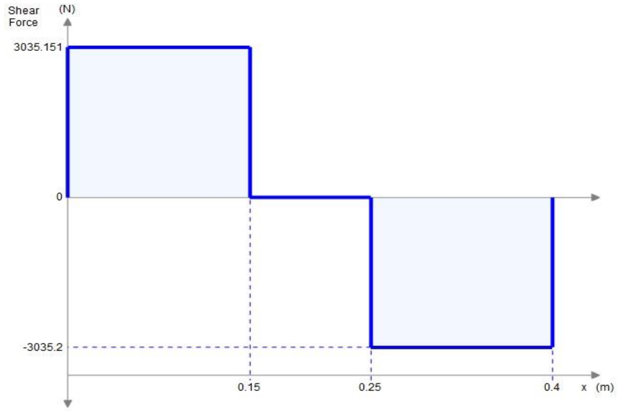


**Fig -1**: SFD of shaft 2

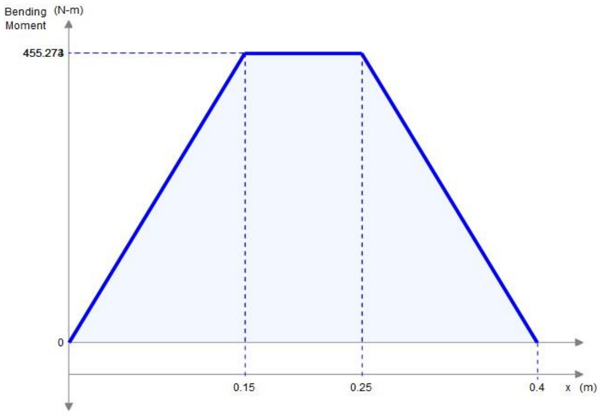


**Fig -1**: BMD of shaft 2

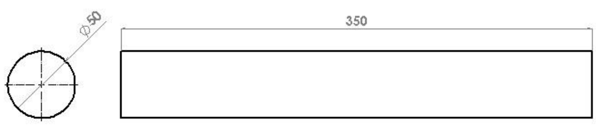


**Fig -9**: Drafting of shaft 2

### 3.4 Design of Locking Plate

Outer diameter of locking plate=95 mm
Inner diameter of locking plate=50 mm
Pitch circle diameter for bolts=75 mm

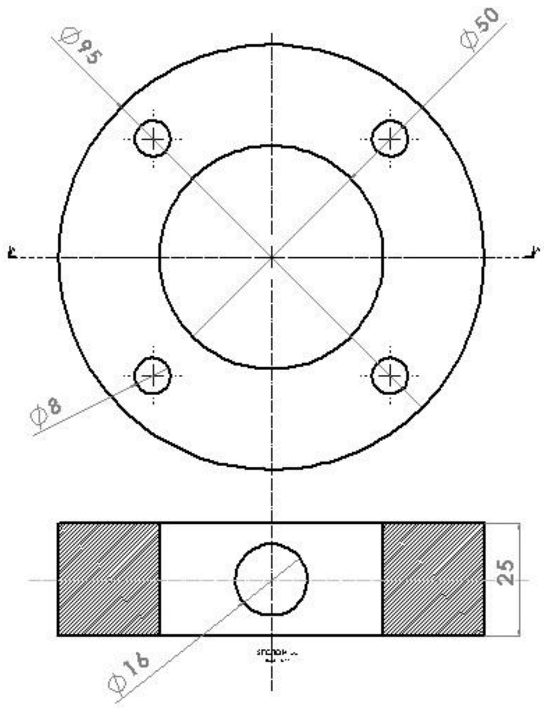


**Fig -10**: Drafting of Locking plate

### 3.4 Design of Grub Screw

$d_1$=grub screw diameter
$d_1$=0.125×shaft diameter+8mm
$d_1$= (0.125×50) + 8
$d_1$=14.25mm
$d_1$=16mm
Length $l_1$=25mm
Grub screw selected is M16×2.

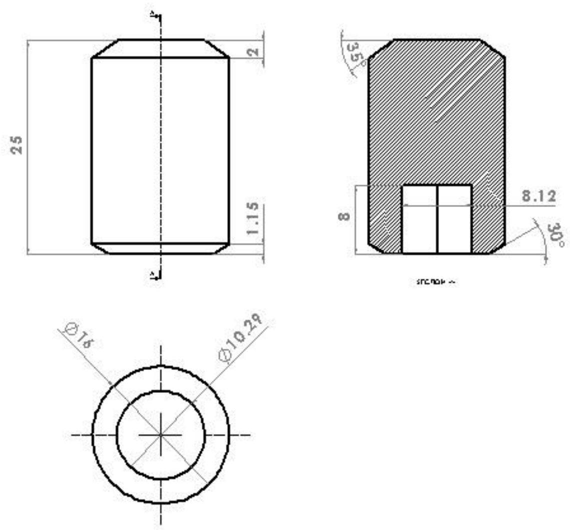


**Fig -1**: Drafting of grub screw

### 3.5 Design of Bolt

Number of bolts=16
Size=M8×1.25 and length is 70 mm

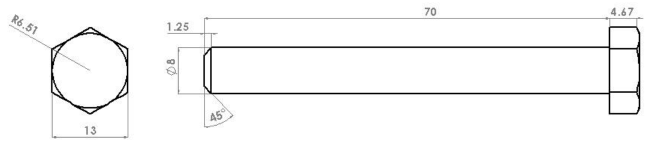


**Fig -1**: Drafting of bolt

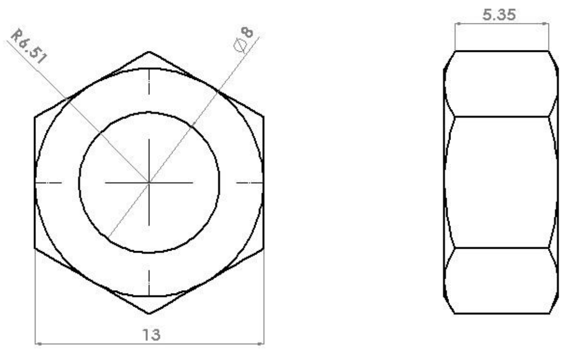


**Fig -1**: Drafting of Nut

### 3.6 Bearings

Shaft1 is supported on bearing, radial reaction at bearing is 3688.2 N.

Static equivalent radial load:
$P_o= X_oFr+Y_oF_a$
$P_o=F_r$ ……………………whichever is maximum
Where,
$X_o$=Static radial load factor=0.6
$Y_o$=Static axial load factor=0.5
$F_r$=Actual static radial load=3688.2 N
$F_a$=Actual static axial load=0

$P_o$=(0.6×3688.2+0.5×0)=2212.92 N and
$P_o$=3688.2 N which is maximum.

Equivalent dynamic load:
$P_e= (XVF_r+YF_a)K_a$
Where,
X=Dynamic radial load factor=1
Y=Dynamic axial load factor
V=Rotation factor=1 (inner race rotating)
$F_r$=Actual dynamic radial load
$F_a$=Actual dynamic axial load
$K_a$=Load factor=2.5 (impact load)

$P_e$=(1×1×3688.2+0)×2.5=9220.5 N

For the safety of the design, the bearing selected should be such that $C_o > P_o$.
We select the bearing 6010 having basic static capacity Co=16 KN.

Principal Dimensions of single-row deep-groove ball bearing:
Bore diameter d=50mm
Outside diameter D=80mm
Width of bearing B=16mm.

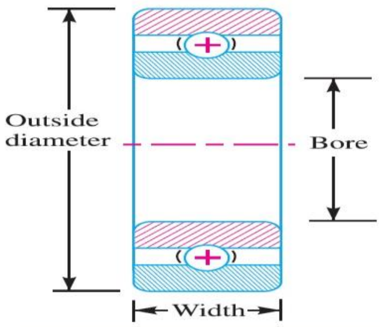


**Fig -11**: Standard designation of Bearing

### 3.6 Design of Hydraulic cylinder for lifting of plate

**Table -1:** BS: 5785 1980.

| Piston diameter(mm) | | 40 | 50 | 63 | 80 | 100 | 125 | 140 |
|---|---|---|---|---|---|---|---|---|
| Piston rod Diameter(mm) | Small | 20 | 28 | 36 | 45 | 56 | 70 | 90 |
| | Large | 28 | 36 | 45 | 56 | 70 | 90 | 100 |

| Piston diameter(mm) | | 160 | 180 | 200 | 220 | 250 | 280 | 320 |
|---|---|---|---|---|---|---|---|---|
| Piston rod Diameter(mm) | Small | 100 | 110 | 125 | 140 | 160 | 180 | 200 |
| | Large | 110 | 125 | 140 | 160 | 180 | 200 | 220 |

Hydraulic Cylinders can be selected as a standard component with maximum safe pressure of 210 bar.
Force required=Total reaction at shaft2+(crankshaft weight× 9.81)
=2× 3035.14+200× 9.81
=8032.28N
=818.784 kg
Cylinder stroke=0.6 m

Minimum piston rod diameter to prevent buckling of rod:

Buckling load $K=\frac{\pi^2 EI}{SL^2}$

E=Modulus of elasticity of piston rod (Steel)=2.1× $10^6$ kg/cm$^2$
S=factor of safety=5
L=Maximum distance between trunion and piston rod eye=2× 0.6 =1.2m=120cm

$K = 818.784=(\pi^2\times2.1\times10^6 / 5\times120^2)\times(\pi / 64)\times d^4$
d = 2.759 cm=27.59 mm
Selecting next standard diameter
d=diameter of piston rod=28 mm
Assuming maximum pressure of 180 bar at cylinder
A=Area of cylinder=818.784×9.81/180 ×$10^5$=446.2372 mm$^2$
$A_r$=Area of rod side = $\pi$ d$^2$/ 4=615.7521 mm$^2$
$A_p$ =Area of piston side=A + $A_r$ =1061.9893 mm$^2$
$A_p=\pi D^2 / 4$
D = Diameter Of piston = 33.504 mm

Selecting next standard diameter
D = 40 mm
Pressure required for 40 mm bore diameter and 28 mm rod diameter to lift load of818.784 kg
$P=(818.784\times9.81) / (\pi\ 40^2 / 4)$=63.918 bar
During retraction:
$P=(818.784\times9.81) / (\pi\ (40^2 -28^2)/ 4)$=125.33 bar

## 4. RESULTS AND DISCUSSIONS

The new mechanism is designed for crankshaft transfer in ALFING machine (Induction hardening machine). With the application of new mechanism, the existing linear motion bearing is replaced with a simple part transfer mechanism based on gravity principle .The new mechanism is not affected by the coolant used in quenching operation. The time taken by the crankshaft to travel the required distance is reduced due to increase in travelling speed caused by the combined effect of the gravitational force and the momentum provided by hydraulic cylinder. Thus the crankshaft transfer cycle time is reduced. As there are no moving parts involved, the maintenance required for the new system is less. The system can be further modified to control the speed of the crankshaft and also to reduce noise caused during operation.

## 5. APPLICATION AND FUTURE MODIFIACATIONS

Part transfer mechanism is used to transfer a part from one place to another during machining operation. The working principle of the designed mechanism is rolling of the job with the help of gravity. But in this design the velocity of the job to be machined is not controllable. This is one of the disadvantage of the gravity type of part transfer mechanism. To overcome this problem a trolley is mounted on the designed plate and it is moved with the help of a chain drive and powered by an electric motor. This will help in controlling the speed of the part to be transferred. To reduce the cycle time, two grooves on the plate at the machine spindle end can be used. With the usage of two grooves the raw crankshaft can be parked at the other end of the plate which is beyond the point of spindle. When the hardening of the crankshaft is completed, it is rested on the plate below the spindle position. By providing negative inclination, the finished crankshaft is brought to the loading position and the raw crankshaft is rolled to the spindle position. Hence the cycle time of the part transfer mechanism is reduced.

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